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by Dr. Trent

MODERN SYSTEMS OF ASCERTAINING STRESS STRAIN

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POWDER METALLURGY

Paper presented to the Institution, Derby Sub-Section on 18th December, 1944, by Dr. Trent

Introduction.

By Powder Metallurgy we mean the art of making metal powders, and from these powders making metal articles by applying pressure and heat. The temperatures used are such that the major part of the metal and sometimes all the metal remains solid. This distinguishes it from other processes of metal production in which the entire metal or alloy is melted at some stage.

Obviously it is a useful method of producing and fabricating those metals whose melting points are so high that they cannot be melted or are very difficult to melt. This was true in the last century for both platinum and tungsten, and more than 100 years ago platinum was being produced by powder metallurgy, although nowadays with the higher temperatures which can be attained commercially it is melted and cast. Thus powder metallurgy is not very new, but as a method of fabricating large numbers of parts on a mass production scale, it is one of the most recent methods developed by the metallurgical industries.

The potentialities of the process have not yet been realised by the industry itself, and to a still smaller extent by the potential users. This is particularly true in this country, while in America somewhat more progress has been made—all the large automobile concerns have sections devoted entirely to powder metallurgy. The developments which have taken place during the last few years have to some extent been kept secret on account of the war.

As it is a new process in one respect, and as its potentialities have not been fully developed it is necessary to ask, not only what has been accomplished up to the present, but along what lines is it developing, and in what direction are future applications likely to be made?

There seem to be two main directions in which it can develop—one is to produce new metals and alloys with special properties which are considerably better than the more "normal" materials which they replace. This was the original field of powder metallurgy and used to be considered its only field of use. New specialities of many types are still being produced but there is also another direction in which powder metallurgy has been applied and that is to

produce articles which may not have such good properties as those made from wrought or cast metals, but are made by powder metallurgy in order mainly to reduce the cost of manufacture.

I will now deal with these two trends in powder metallurgy in somewhat more detail. First the production of metals and alloys with special properties, and which cannot be produced in any other way.

Two examples have already been mentioned. The metals platinum and tungsten and molybdenum have very high melting points, and the normal methods of production of tungsten and molybdenum wire, sheet or bar is by powder metallurgy. The powdered metal is pressed into bars which are just strong enough to handle. The bars are then heated in two stages to a temperature close to the melting point of the metal (3370°C. for tungsten and 2700°C. for molybdenum), the latter part of the heating being carried out by passing a large current through the bar enclosed in a vacuum chamber, or chamber filled with hydrogen. The temperature never reaches the melting point of the metal at any stage, but at temperatures near the melting point the particles are welded together, and on cooling, the bar of metal is strong and hard, but is brittle and contains considerable porosity so that the specific gravity or density is only about 95 % of the density of the solid metal.

At this stage tungsten metal can only be hot worked, but after hot working, it can be cold drawn to extremely fine wires for lamp filaments; in the cold drawn wire has the highest tensile strength of any material—about 380 tons per square inch. Thus while some powder metallurgy products are of comparatively low strength and ductility, these are not necessarily characteristics of the products of powder metallurgy.

Another type of special alloy which is produced by powder metallurgy is an alloy in which the two metals have very different melting points, or in which the two metals separate into layers on melting because they are not soluble in each other.

Of this type of alloy there are several examples. The tungsten carbide alloys which are so extensively used for machining metals for drawing dies and for wear resistant parts consist of a very hard substance tungsten carbide which has a very high melting point (2600°C.), and is also very brittle. It can be reduced to a powder and bonded or cemented together by another metal powder, usually cobalt, which melts at a much lower temperature (1490°C). In this way an alloy is made which could not be made by any other process and which is harder than any other material in common use with the exception of diamond, and which can be used to machine metals and draw wire at many times the speed of the other materials available.

There are also the electrical contact materials. These materials

for breaking heavy currents at high voltages have to possess a most elaborate combination of properties which are not found in any one metal or in normal alloys. These properties include high conductivity of electricity and heat, high hardness, resistance to oxidation, high melting point, etc. Silver and copper have high conductivity but low hardness and melting points. Tungsten has high melting point but low conductivity. A mixture of these two metals gives the desired properties, and very good electrical contacts are made from silver tungsten, copper tungsten, and similar materials. These materials do not alloy in the usual sense of the word and when examined under the microscope are seen to consist of a mixture of the two metals. During the process of production the shaped blocks are heated until the silver melts but the tungsten remains solid. Thus both the contacts and the hard metals illustrate materials which can only be made by powder metallurgy and in which, during sintering, part only of the material melts and cements together the solid particles. This process may also be extended to the production of copper lead bearings.

A third type of special material includes the various materials which are now produced combining metals and non-metals. It is fairly obvious that by powder metallurgy it is very easy to incorporate into your material almost any substance which can be reduced to powder form, non-metals as well as metals, and while "non-metallic inclusions" are generally thought of as impurities to be got rid of, nevertheless very useful properties can be obtained by adding definite quantities of non-metals to metals. Here let me stress that the ease with which the constituents are mixed by powder metallurgy enables the composition to be controlled very accurately, and also makes possible accurate control of the distribution of the materials added.

One of the first uses of the addition of non-metallic materials was in tungsten wire to which thoria and silica were added to produce non-sagging wires, by preventing or restricting grain growth.

Other examples are the metal bonded diamond wheels, which are used for grinding hard materials, and drills for drilling hard rocks. In these the diamonds of various grades and sizes can be mixed with a metal usually either iron or bronze powder and pressed into the form of the wheel and sintered. The metal bonding grips the diamonds firmly and wears away more rapidly than the diamond, but less rapidly than bakelite or other plastic binders.

Welding rods can be made from metal or alloy powders and can include a powdered flux. Such rods can give good results in welding.

Recently in America a new type of friction material for brake linings and clutch facings, etc., has been developed. This is of use mainly where the load is high and the conditions are severe so that the normal linings—composed usually of asbestos and a plastic

binder—are destroyed by the excessive heat generated during operation. In this case the material is usually based on a bronze containing 60%—70% copper and 7% tin. In addition, finely divided silica in amount up to about 6% is added to increase the coefficient of friction ; graphite and lead in the form of powders are added up to 7% and 15% respectively to prevent scoring of the surface and wear, and 8% iron is usually added to increase the hardness. This extremely complex material with quite a high content of non-metallic matter, is sintered under pressure on to a steel backing plate since it does not possess sufficient strength to be used alone. It is claimed that this material can be used at much higher working temperature than can the normal type of brake lining ; and, therefore, under higher loads. It is thus useful for severe conditions such as aeroplane and tank brakes and clutch plates, and has been suggested for use in such jobs as colliery winding engine brakes.

The fourth type of special materials which I want to mention comprises the largest number of parts made. These are the porous metal parts—mainly bearings of a porous bronze which are now familiar in most industries. Bearings of many sizes and shapes are made but the majority are comparatively small and of simple design. These bearings are impregnated with oil and this oil is fed continuously to the bearing surface. Graphite is also sometimes included in the composition and this acts as an additional lubricant.

These bearings are now used very extensively in industry for such things as fractional horsepower motors, instruments, aircraft controls, textile machinery, etc. They have been approved for use on aircraft at pressures up to 3,000 lbs. per square inch. The advantages include self-lubrication, very low oil consumption compared with other types of bearing, and reduced wear. The cost is competitive with machined bronze bearings.

This porous structure in metals is one which can only be produced by a powder metallurgy process, and the fineness and character of the porosity can be varied by varying the grain size, etc., of the different constituents. The character of the porosity can be varied for different applications. Strong metal filters can be made in a similar way for certain industrial chemical processes, etc.

Permanent magnets of high coercive force of the "Alnico" type are now made by powder metallurgy in the smaller sizes (under 2 ounces weight). The reason for this is that the cast material cannot be forged, and is very difficult to shape except by grinding. By powder metallurgy a product which has nearly as good magnetic properties, better mechanical strength, and is finished to within close tolerances after sintering, can be produced.

Apart from the various fields of special alloys, some of which have just been described, but of which there are many that have not

been mentioned, there is also a newer field into which powder metallurgy is making its way. It is too early yet to say how far powder metallurgy will go in this field, but it has interesting possibilities. This field is the mass production of parts which have no special properties but are produced in this way because powder metallurgy offers certain definite advantages and economies.

Among these advantages is the small amount of scrap produced in the process. In the production of many parts a very large percentage, often over 50% of the weight of a part is lost in the machining of the casting or forging or in the scrap resulting from blanking parts out of sheets. In making parts from powder metallurgy there is generally no machining after pressing and no loss due to scrap since exactly the right amount of powder to make the piece is fed into the die and pressed to shape. In many cases also, many operations apart from machining can be eliminated by using powder metallurgy. In some respects this use of powder metallurgy can be compared with die casting. The properties of the parts made in this way are generally somewhat poorer than those made by casting or from wrought metals, and they are generally used in applications which are not highly stressed, although this is not always true—for instance, piston rings of powdered iron are being considered.

This side of powder metallurgy is being developed in America but has so far been not much used in this country, so that it will not be possible for me to give you figures for comparative costs. Two examples will be mentioned—one of which has been put into production by the General Motors Corporation in America. This is their oil pump gear. This was formerly made of cast iron and 64% of the cast slug was removed in machining. It is now made from iron and graphite powders, pressed to shape, sintered for about 20 to 40 minutes at about 1100°C. and is then practically ready for use. It has a porosity of about 20% and is impregnated with oil. The mechanical properties are similar to those of an average cast iron—tensile strength 10/12 tons per square inch, and the contour of the teeth is better than that obtained by machining, which leads to quieter running of the oil pump.

A second example, which has been quoted by Dr. W. D. Jones, one of the best known authorities on powder metallurgy in this country, is the possible use of the process for producing coins. This example illustrates the potentialities of powder metallurgy very well. The usual process of melting, casting, hot and cold rolling, blanking and stamping, necessarily involving a considerable percentage of scrap which must be remelted and retreated, could be replaced by a much simpler powder process in which the metal powders could be mixed to give an accurately controlled composition, pressed in one operation to a blank, sintered, and finally struck in a coining press with practically no scrap and without the melting

and hot and cold rolling processes. The advantages of this case are obvious.

A complete list of the metals and alloys which can be used in powder metallurgy would be very long, but apart from the specialities, they include iron, steel, alloy steel, " cast iron," bronze, copper, aluminium bronze, aluminium, dural, etc.

A table giving some typical properties of pressed and sintered powder metallurgy products is shown below. Much improved properties can, of course, be obtained by hot working but at additional expense.

	Density GM/CC³	Tensile Strength tons/in²	Elongation %	Brinell Hardness
COPPER.				
Pressed and sintered	7–8	8–12	10–20	30–40
Sand cast	—	25	20	—
Hot pressed	8.4	14–17	—	120
BRASS.				
Pressed and sintered (90 Cu, 10 Zn)	—	15	18	—
Pressed and sintered (70 Cu, 30 Zn)	—	18	60	—
Pressed and sintered (60 Cu, 40 Zn)	—	22	25	—
Soft annealed (70 Cu, 30 Zn)	—	22	64	—
TIN BRONZE.				
Oil-less bearings (90 Cu, 10 Sn)	—	6–8	5–10	25–40
Pressed and sintered (95 Cu, 5 Sn)	8.2	10	2	72
Pressed and sintered (90 Cu, 10 Sn)	7.9	—	—	100
Hot-pressed (90 Cu, 10 Sn)	8.7	23	—	135
PHOSPHOR BRONZE.				
Pressed and sintered	8	9–14	0–9	85–100
ALUMINUIM BRONZE.				
Pressed and sintered { (85 Cu, 5 Al, 5 Ni, 5 Fe) ...	6.0	—	—	58
{ (80 Cu, 12 Al, 5 Ni, 3 Fe) ...	6.0	—	—	150
Hot-pressed (94 Cu, 6 Al)	8.0	15	—	197
Hot-pressed (90 Cu, 10 Al)	7.5	17	—	197
Hot-pressed (88 Cu, 12 Al)	7.3	8	—	226
ALUMINIUM.				
Pressed and sintered	—	8–9	19–35	—
ALUMINIUM ALLOYS.				
Pressed and sintered	—	22–24	10	—
COBALT.				
Pressed and sintered	8.34	—	—	230
IRON				
Pressed and sintered	6.5–7	11–10	8–12	40–50
Ingot iron	7.8	24–26	22–28	—

NOTE.—On account of the great differences in the types of powders and methods of processing used in this and other countries, in the above table it is possible to give only a wide range of figures for each property.

As will be seen, the tensile strength is generally lower, and the ductility as measured by elongation is considerably lower than for cast metals, which is why this process is generally used for lightly stressed parts.

It should be emphasised here that in any proposal to use powder metallurgy there should be close co-operation between the firm supplying the powder and those using it, to ensure that the properties of the product are what is required. The usual specification of composition, etc., should pretty well be forgotten because it may be necessary to use quite different materials to take proper advantage of the powder metallurgy process. Die casting has developed new alloys, based on zinc, which are particularly useful for die casting. Thus it is important for the user to specify not so much the composition but the properties required, and it may even be necessary to work not on the normal test results (in particular, hardness test results on powder metallurgy products are misleading), but on service tests.

Some of the advantages of the powder metallurgy process have been mentioned, but it would be very misleading to suggest that it has not disadvantages and limitations. It leads to much disappointment and waste of time if the applications proposed are for one reason or another unsuitable, either because the shape is unsuitable for pressing, the properties desired cannot be achieved, or because it would be more costly than the normal methods and have no great advantages. For this reason it is important for you to know the limitations and so that you can understand these I want to give you an outline of the processes of powder metallurgy.

Metal and alloy powders are produced by a number of different methods, and no one method is likely to replace all the others—each has its field and the characteristics of the powders produced depend to some extent on the method of production of the powders.

In the first place, powders can be produced by mechanical disintegration. If the metal be brittle, like antimony for instance, or if a brittle alloy is to be used such as 50/50 iron-aluminium or copper-aluminium alloys, these can easily be reduced to powder by jaw crushers, pulverisers with counter rotating plates or rapidly rotating hammers, etc., following by ball milling if a very fine powder be desired. These brittle alloys and metals are thus easily produced in bulk in any desired grain size from a tenth of an inch to a thousandth of a millimetre or smaller. The particles are irregular in shape but approximately equi-axed, *i.e.*, not long and narrow or flat and plate-like. For soft and malleable metals on the other hand, this process is not very suitable since the particles are hardened by cold work and also tend to be flattened out into flakes like the aluminium and bronze powders which are used for paints. Such flake-like powders do not press well and are avoided generally in powder metallurgy. Some cheap powders—iron in particular—are produced by pulverising turnings and these have been successfully used for some jobs.

An alternative to pulverising the metal is to pulverise some compound of the metal usually the oxide which is usually easily reduced to powder form. The oxide can then be reduced to metal by heating with carbon or in a current of hydrogen, etc. Iron, coppor, tungsten, nickel and other metals can be produced in powder form in this way. It is the only convenient way of producing such metal powders as tungsten and molybdenum which have very high melting points. Supplies of oxide of iron and copper are available in the form of purified ore, mill scale, etc., but are not particularly cheap in this country. In Sweden a very pure iron ore is available and a cheap but good iron powder used to be, and probably still is, produced by heating the pulverised ore with charcoal. One of the disadvantages of this method is that the starting material must be fairly pure since almost all of the impurities remain in the metal powders—silica for instance in iron powder. The powders produced are generally fine but the particles tend to be spongy and hence the powder is bulky. The particles are very irregular in shape and often do not flow readily.

Some metals cannot be produced by either of the above processes; —aluminium oxide for instance is not reduced by carbon or hydrogen at normal temperatures. Lead and tin oxides can be reduced but only at temperatures above their melting points. These metals can be reduced to powder by an atomising process which is similar to a process used in metal spraying. A stream of the molten metal is allowed to fall into a jet of air, steam or other gas which disintegrates it into a fine spray that is allowed to settle in a large settling chamber. The particles produced in this way are generally rounded or dumb-bell shape or tear drop shape, and are much smoother and less angular than the powders produced by the other methods mentioned. These powders are generally coarser than reduced powders and flow more readily. The process is cheap; powder can be made from re-melted scrap, etc., and for certain purposes the powders are very useful. For instance, for making light alloys of aluminium base, the aluminium is best produced in this way. The process is limited by the melting point of the metals —aluminium, tin, lead, solder, zinc and bronze can easily be produced but not ferrous metals and alloys.

A fourth method is by electrolysis. It is well known that under bad conditions an electroplater will get a powder deposited in place of a smooth coating. This effect is utilised and by deliberately altering the conditions of the plating bath—the current density, acidity, etc.—a powder is formed at the cathode which is easily detached and falls to the bottom of the plating bath from which ti can be removed at intervals. Iron and copper are the powders which are mainly produced by this method although some alloys

can also be produced. Electrolytic iron and copper powders are produced in bulk (many tons a day) in America, and also now in this country. The copper powder can be particularly cheaply produced since there are large electrolytic copper refineries in which the powder is produced by minor alterations to existing plating conditions. The powders produced in this way are usually pure as most of the non-metallic impurities are eliminated in the process. The particles are sometimes dendritic, *i.e.*, long and branched like a pine tree, and sometimes nodular or flaky and the shape can be altered at will to suit the requirements. The particle size can also be altered at will, within limits, to produce fine bulky powders or more dense and free flowing powders. This process is cheaper than reduction of the oxide and will probably be responsible for a large proportion of the iron and copper powder in the future.

There are also other processes used such as the carbonyl pro cess for iron and nickel, but the above four are responsible for the bulk of the powder produced.

The sort of powder used, and the grain size are determined by the particular application. For instance, if the part must be of high density a fine powder is generally required. If high porosity be required with fairly large pores, coarser powders will be used. When rapid acting automatic presses are used a free flowing powder must be employed.

The grain size and the flowing quality of the powder are frequently both specified in ordering a powder. The grain size is generally specified as the percentage of the material which will pass through sieves of different mesh sizes. The flowing quality of the powder is expressed as the quantity of powder flowing through a standard orifice in a standard time.

Here I want to say something about the pressing process. First, what pressures are required? This depends on the powder. Soft metals require in general a lower pressure than hard metals. Copper and bronze can be pressed at about 10/15 tons/sq. inch, while to make a high density part from an iron alloy will require about 30 tons/sq. inch and it will give better properties when pressed at 50 tons/sq. inch. This pressure has an important effect on the life of the dies, wear being much more rapid at higher pressures. Since the cost of dies is high, if only a small number of parts can be pressed before the die is worn out the cost per part will be uneconomical. The die life, of course, depends on the particular job but if an average figure can be given I should say that a die should produce at least 10/50,000 parts. This often limits in practice the pressure which can be used.

The dies must be made of good quality die steels—air hardening nickel chrome steel, high speed steel, etc., and it may be economical, where the number of parts required is large, to line the dies with a cemented carbide.

Where small numbers of parts are to be made (and this is not usual) or where the parts to be made are large—large hydraulic presses with comparatively slow action are employed. The dies may be made in several pieces so that they can be taken apart to extract the pressed compact. You will have noticed that the pressures employed are quite high so that for large parts several square inches in area very large presses of several hundred tons or several thousand tons capacity are required.

Where large numbers of parts are to be made, rapid acting automatic presses are used. The die is automatically filled with powder and, after pressing, a bottom plunger ejects the pressed compact. Using a single die, about 30 parts per minute can be made, and with multiple dies up to 600 parts per minute have been made. It is obviously necessary in such cases that the powder shall flow rapidly into the die, *i.e.*, the powder must be free flowing. Rapid acting mechanical presses are limited in capacity so that the size of the parts which can be produced is limited for this reason.

Here I want to mention the second major limitation on powder metallurgy which is that the shape of the articles which can be produced is limited. This is because the powders, unlike plastics, do not flow readily under pressure. For instance, if a long cylinder be pressed from the top the whole of the pressure is not transmitted from top to bottom of the powder. Due to friction on the walls of the die, pressure on the bottom of a piece of which the length is three times the diameter may be only a quarter of the pressure on the top. This means that the bottom will be less densely packed, less hard and less strong than the top. This can be partly overcome by pressing from both ends.

Another effect of this lack of flow under pressure is that complex shapes are difficult to press. The thickness of the part in the direction of pressing should, if possible, be constant. Parts with two or more different thicknesses can be pressed but require dies with two or more plungers acting independently. Re-entrant angles cannot be moulded nor can screw threads, and such things as holes at right angles to a central hole also present an impossible problem. The oil pump gear mentioned earlier presents an example of an easily moulded part, while a good example of an impossible part would be a cylinder block with fins moulded in. It is not easy in a short time to deal with this question of shape, but it should be obvious that the shape has a great deal to do with whether a part can be economically produced by powder metallurgy, and also that the

advice of an engineer experienced in the processes should be sought before deciding on making any part by this process.

After pressing, the parts possess a certain amount of strength but must be sintered. This means heating to some temperature which depends on the particular metal or alloy, usually in an atmosphere of burnt Town's gas, cracked ammonia, hydrogen or some neutral or reducing atmosphere. In this process the particles weld together, and where a mixture of different powders is used, alloying takes place. The material thus acquires its final shape and strength. The sintering is usually carried out in continuous furnaces the work being pushed through in boats on rollers, or on a conveyor belt, etc. Shrinkage or sometimes growth takes place during sintering and to maintain a constant shrinkage or growth the characteristics of the powder must remain unchanged, and pressing pressure must be kept constant. The size should in this way be controlled to within $\pm$ 0.002" to $\pm$ 0.005" per inch. Closer tolerances can be ensured by a final pressing or coining operation in which small alterations are made to the size, and the strength is generally slightly increased.

As mentioned above, the properties of pressed and sintered pieces in general are not as good as those of wrought material. In particular, the ductility tends to be low. The properties can be much improved and in many cases better figures than for ordinary wrought materials can be achieved by hot working after sintering or by cold work followed by re-sintering, but this, of course, does away with the main advantage of the powder metallurgy process—its simplicity—and increases the cost. Thus working and re-sintering are only used for alloys of special properties which cannot be made in any other way, and which I mentioned at the beginning of this talk.

Before finishing I would just like to say a word about another process which has not been used much up to the present, but which may be developed to a greater extent in the future. This process combines the pressing and sintering operations and is known as hot pressing.

The powder is pressed, usually at a lower pressure than is used for cold pressing, and the mould is heated at the same time to some temperature below the melting point of the powder. The powder takes the form of the mould and the density is increased to a figure higher than that attained by cold pressing and sintering. The strength and ductility and other properties are also improved over those obtained by the normal process. There are, however, two big disadvantages which have yet to be overcome. The pressure usually must be applied for a considerable length of time, while the powder is heating up, thus decreasing greatly the output per mould

in a given time, and a suitable mould material is difficult to find in most cases. These difficulties may be overcome and this process may yet become one of considerable importance.

In conclusion I hope I have given you some idea of the wide field which powder metallurgy covers, and of the numerous applications in which it is already being used. I am sure there are many more potential applications and in this connection I hope that in describing the advantages and limitations of the process I will have helped you to find some field in which it would be of advantage to you.

MODERN SYSTEMS OF ASCERTAINING STRESS STRAIN

The following references to work which has been carried out on this subject may be of assistance to investigators.

Photo-Elasticity Method.

The general principle of this procedure is well known, but a considerable amount of work has recently been carried out by the N.P.L. and the University of London.

Stress Distribution by the Maybach Brittle Lacquer Process.

Ref. Article by R. F. Tylecote in *Transactions of the Institute of Welding*, 1942, Volume 5 (3), pages 120—132.

Ref. O. Dietrich (*Metallwirtschaft*, 1940, Vol. 19 (17) pages 337—342.

The Maybach process consists of coating the metal part under investigation with a suitable lacquer which fractures when the metal is lightly stressed. The shape and position of the cracks in the lacquer coating then indicate the direction and magnitude of strains in the metal, even when these are well within the elastic range.

It is thus possible to judge in advance where the greatest stresses are located, and consequently where failure is likely to occur under static or alternating stress, or both.

Deitrich discusses applications of this test to straight and notched components of various materials, shows what additional information can be gained by using different lacquers, and describes how the mechanical properties of the metal can be determined with a limited number of measurements rapidly carried out.

Ref. A. V. de Forest, Greer Ellis and F. B. Stern, Jnr. *J. Applied Mechanics*, 1942, Volume 9 (4) A—184—A—188.

Strain patterns produced in a lacquer coating afford a measure of the strain in the underlying material and may thus be used to study the strain distribution in complicated structures. The use of "Stresscoat" brittle coating materials (composition not stated) is described. The effect of variations from 0.003 to 0.006 in. in the thickness of the coating is not appreciable if the coatings are dried from 15—24 hrs. and the tests carried out at a temperature controlled within $\pm$ 5° F. and at a reasonably constant humidity. The patterns may be correlated with the strain of the underlying metal

by comparison with the patterns produced on a test cantilever strip coated at the same time and deflected by a known amount in a special fixture. Coatings which flake off when the yield-point is approached may also be employed.

Determination by Ultrasonics.

Ref. A Behr, *Metallurgia*, November, 1940, Volume 23, No. 133, pages 7—11.

X-Ray Analysis.

Considerable developments have been made in this process particularly by the N.P.L. and the University of London, and the Woolwich Arsenal Research Department. Up to date information can also be obtained from the manufacturers of X-Ray equipment.

The Electric Resistance Method on Parts Subject to Strain.

Ref. *Production Engineering*, June, 1942.

Ref. A. Theis, *Aircraft Engineering*, 1943, Vol. 15 (170), pages 106—109. Translated from Z. T. Physik, 1941, Vol. 22, (11) pages 273—280.

The technique of strain gauging with the use of strip and ring-shaped gauges is described.

True Stress Strain Tension Tests.

Ref. *Journal of the Franklin Institute*, Prof. C. W. Macgregor. August and September, 1944. Volume 238, Nos. 2 and 3.

Research Department: Production Engineering Abstracts

(Prepared by the Research Department.)

NOTE.—*The Addresses of the publications referred to in these Abstracts may be obtained on application to the Research Department, Loughborough College, Loughborough. Readers applying for information regarding any abstract should give full particulars printed at the head of that abstract including the name and date of the periodical.*

HEAT TREATMENT.

Heat-Treatment of Tank-Track Spindles, by A. R. Page. (*The Machinist, 10th, 17th February, Vol. 88, Nos. 44, 45, 5 pp., 7 figs.*).

Part I. Procedures for hardening short steel bars to close limits of case depth and straightness.

Part II. Methods for checking case hardness and straightness. Bonus scheme to cut down indentor breakages. Relation between grain size and hardenability of the steels investigated to determine heat-treatment.

Fundamental Principles and Applications of Induction Heating. (*Sheet Metal Industries, February, 1945, Vol. 21, No. 214, 6 pp., 9 figs.*).

Part V. Further examples of induction hardening are described, including the continuous hardening of bars, and the use of very high frequencies for the production of thin cases.

BELTS, DRIVES.

Chain Drives in Industry, Part II. (*Power Transmission, 15th February, 1945, Vol. 14, No. 157, 3 pp.*).

This part deals with the classification of chain drives, mechanical details governing selection, and fundamental design relationships.

EMPLOYEES, APPRENTICES.

Education and Training for Engineers. (*Journal of the Institution of Electrical Engineers, February, 1945, Vol. 92, Part I, No. 50, 13 pp., 3 figs.*).

This is the Institution of Electrical Engineers' second report dealing with part-time further education at technical colleges, including courses for those returning from the services. It is proposed that part-time education should be developed to provide for the needs of the three main groups: craftsmen, technicians and future professional engineers unable to take the normal university course. For electrical engineers returning from the services it is suggested that they can be classified in seven groups and the provision of further technical education for them is outlined.

The Future Conditions of Employment, by F. J. Burns Morton. (*Industrial Welfare and Personnel Management, January-February, 1945, Vol. XXVII, No. 298, 3 pp.*).

The continuous trend towards higher wages, better working conditions, longer holidays, improved social services, and the shorter working week

can only be achieved by higher production per man-hour. Since companies making similar products and competing in the same markets use similar machinery and methods, future competition will tend to gravitate round the proficiency of personnel and capacity for organisation. The writer reviews the improvements which may be effected by better human relationships, incentives to work, improved industrial relations, and leadership.

How to Interest the Employee in His Job, by Robert A. Sutermeister. [*Personnel (U.S.A.), November, 1944, Vol. 21, No. 3, 8 pp.*].

The author reviews several methods of instilling responsibility in workers and making them feel that what they do is important.

The Place of Personnel Research as a Management Tool, by C. A. Drake. [*Personnel (U.S.A.), July, 1944, Vol. 21, No. 1, 6 pp.*].

Personnel research, like research in other areas, has potentialities for good and ill. The author here cites actual examples of each application—as tool or as weapon. He further discusses the two current and extreme points of view on the place of research in the organization and emphasizes that management and research personnel must establish its proper orientation within the organization structure.

The Spirit of Reinstatement, by Major R. A. C. Radcliffe. (*Industrial Welfare and Personnel Management, January, February, 1945, Vol. XXVII, No. 298, 4 pp.*).

The actual problems of reinstatement are discussed for men in four main categories :— (a) Those who want to return to their old job and want nothing different. (b) Those who want to be considered for a better paid job under the clause which says they must be reinstated on terms and conditions not less favourable than those which would have been applicable in that occupation had they not performed war service, where it is reasonable and applicable to do so. (c) Those who want employment with the old firm, but whose return to the old occupation is not practicable. (d) Those who want reinstatement but whose old job no longer exists. Other factors affecting the spirit of reinstatement, including relations between service and non-service employees are also considered.

Postwar Employment of Veterans, by Brigadier General William C. Rose. **Problem of Returning Service Man from Labour Viewpoint,** by Clinton S. Golden. **Industrial Jobs for Returning Veterans,** by Stewart M. Lowry. **Veteran Re-employment,** by D. M. Mason. [*Mechanical Engineering (U.S.A.), January, 1945, Vol. 67, No. 1, 10 pp.*].

The first three articles deal respectively with the employment of ex-servicemen from the government, labour and management points of view, while the fourth comments on them and relates their conclusions. Since they are concerned with U.S. legislation, their recommendations are not directly applicable, but the basic difficulties are similar.

How to Plan for Post-War Employment, by G. F. Davenel. (*Personnel, U.S.A., Vol. 21, No. 2, 9 pp.*).

Much of the current planning for postwar employment is nebulous and impractical. The article suggests several down-to-earth suggestions on assisting displaced war workers to find profitable employment in civilian life, and advocates the establishment of well-rounded company programmes of vocational

guidance, through which displaced workers may be directed to related occupations where opportunities for placement exist. The selected reading list given will provide the nucleus of a vocational information shelf.

Post-War Developments in Joint Consultation, by L. H. Pearmaine. (*Labour Management, December-January, 1944-45, Vol. XXVI, No. 277, 4 pages*).

This address by a prominent Trade Unionist deals with the development of Whitley Councils, improvements needed in the system, shop stewards and management, and post-war problems suggested for union officials; the need for efficiency all round after the war is noted.

Personnel Counseling in the United States and Great Britain, by Patricia Elton Mayo. (*Labour Management, December-January, 1944-45, Vol. XXVI, No. 277, 3 pp.*).

The functions of the personnel counsellor range from the administrative functions of a personnel department representative working in a production department to the functions of a skilled psychiatric social worker with no administrative duties. This originated in the U.S. about eight years ago, but a similar development is taking place in Great Britian. British and American practice are described and compared in considerable detail.

FOUNDRY.

Dust Suppression in the Fettling Shop. (*The Commonwealth Engineer, 1st November, 1944, Vol. 32, No. 4, 2 pp., 3 figs.*).

The arrangement of dust handling plant for a fettling shop.

The Development of Grey Iron Die Castings, by H. K. Barton. (*Machinery, 22nd February, 1945, Vol. 66, No. 1689, 4 pp., 4 figs.*).

Metal moulds. Pressed-steel die cavities. Open-mould die casting. Melting technique. The Holley process. Operating the Holley machine. Air-Cooled dies. Dressing the dies. Increased production.

GEARING.

Resilient Gear Drives, by R. Waring-Brown. (*Power Transmission, 15th February, 1945, Vol. 14, No. 157, 4 pp., 7 figs.*).

Specially designed gears are often essential as a protection against shock and overload in the gear drives of reciprocating pumps, air compressors, power presses, punching and shearing machines, planers, shapers and transmission systems. Modern developments in flexible gears are described and illustrated.

Disabilities of Gear Manufacture, by E. W. Mace. (*Mechanical World, 2nd February, 1945, Vol. 117, No. 3031, 2 pp.*).

The effects of production methods on the performance of gears are described. The processes discussed include dróp forging, machine forging, machining, heat treatment and cold working.

HEATING.

Industrial Applications of Infra-Red Heating, by F. E. Rowland. (*The Machinist, 24th February, 1945, Vol. 88, No. 46, 3 pp., 4 figs.*).

Part I. General principles. Applications for paint drying.

MACHINE ELEMENTS.

Drawing Office Practice Relative to Interchangeable Components, by C. A. Gladman. (*Machine Shop Magazine, February, 1945, Vol. 6, No. 2, 7 pp., 10 figs.*).

Part 2. This deals with positional work, and a detailed analysis is given of a pair of mating components. Details are given of a shorthand whereby symbols can be used to indicate on drawings positional groups and position tolerances, and full information can be given without need for lengthy notes.

(*Extracts from this paper are also given in Production and Engineering Bulletin, January, 1945*).

The Dimensioning of Production Drawings, by W. Barnes. (*Machinery, 1st February, 1945, Vol. 66, No. 1686, 5 pp., 9 figs.*).

Part II. Disadvantage of chains of limiting dimensions. Selection of the reference or datum surface. Dimensioning for more than one set of operations. Comparison of the unilateral and bilateral tolerance systems. Geometric tolerances. Factors which influence the determining of limits and tolerances.

Ball-bearing Spindles for Precision Applications, by W. Boneham. (*Machinery, 22nd February, 1945, Vol. 66, No. 1689, 4 pp., 3 figs.*).

The many advantages possessed by the ball-bearing spindle compared with the plain bearing type are described briefly. Such bearings are widely used, but in connection with grinding and fine-boring, much diversity of opinion is to be found, particularly as to the ability of a ball-bearing spindle to produce a surface finish equal to that produced by an equivalent plain-bearing spindle. It is stated that the results obtained from a modern ball-bearing spindle specially designed and built for its intended purpose, equals or even surpasses the results obtained from a plain-bearing spindle as regards surface finish, plus the advantages already mentioned, provided a special manufacturing procedure is followed. Applications to: internal and face grinding; fine boring; form grinding; surface grinding; and external grinding are discussed, and results of comparisons of finish made by a surfacemeter are given.

Oil Grooves in Plain Bearings, by D. Clayton. (*Power Transmission, 15th February, 1945, Vol. 14, No. 157, 9 pp., 6 figs.*).

Part I. An investigation was started to find the effect of holes and grooves on the behaviour of plain bearings, and this paper describes the first results obtained. The test bearing had a unidirectional steady load; the first part of the paper deals with grooves in the unloaded part of the bearing and the second with grooves in the loaded part. It was intended that, in addition to providing further fundamental understanding of fluid film lubrication of bearings, the work should be in the nature of an analytical approach to the problem of flow through internal combustion engine bearings, but much of the information is of general use. The test machine and conditions, and the general bearing behaviour are first described. The results for various types of grooves in the unloaded portion of the bush are then discussed.

MACHINING.

Grinding Accurate Cam Surfaces. (*Machinery, 22nd February, 1945, Vol 66, No. 1689, 4 pp., 7 figs.*).

Points to be considered in grinding cams, eccentrics and elliptical or relieved pistons.

Machining of Copper : Comparative Efficiency of Diamond and Other Tools, by P. Grodzinski. (*Met. Ind., December, 1944, Vol. 65, No. 24, 4 pp.,*).

Examples of suitable tools and of the production obtainable on pure Cu and Cu-mica laminations.

(*Communicated by the British Non-Ferrous Metals Research Association*).

Machining Steel and Cast-Iron with Diamond, by Paul Grodzinski. (*Industrial Diamond Review, January, 1945, Vol. 5, No. 50, p. 18*).

Brief notes on part applications of diamond tools on ferrous materials.

CHIPLESS MACHINING.

Aluminium Alloy Forging, by L. W. Davis. (*Aircraft Production, February, 1945, Vol. VII, No. 76, 6 pp., 10 figs.*).

The author reviews in a thorough manner some of the more important points to be considered when producing aluminium alloy forgings for aircraft use. These include the choice of materials and the design of dies and presses.

MANUFACTURING METHODS.

Motion Study, Part III. (*Production and Engineering Bulletin, January, 1945, Vol. 4, No. 26, 5 pp., 9 figs.*).

Several examples of the benefits of motion study in the manufacture of light electrical equipment are illustrated and described.

Motion Study is the Missing Function, by S. Bloye Dipple and Brian R. Stephens. (*Machine Shop Magazine, February, 1945, Vol. 6, No. 2, 3 pp.*).

Part II. Some machine makers have designed their machines so that motion study principles can be employed in their operation, but much has been left to the user. Power presses, milling machines, production drilling machines, and capstans can all be improved. Greater publicity for motion study is required : it should be " put over " to all concerned as quality control, negative rake, etc., have been.

Mechanical Engineering in the Shipyard, by J. Foster Petree. (*Engineering, 2nd, 9th, February, 1945, Vol. 159, Nos. 4125, 4126, 9 pp., 21 figs.*).

The article is principally concerned with the history and development of equipment of types not usually found in general engineering use. A number of recent machines are described, including flame cutting machines and plate edge planers.

Batch Production, by T. P. N. Burness. (*Mechanical World, 23rd February, 1945, Vol. 117, No. 3034, 2 pp.*).

Its effect on choice of manufacturing plant is discussed from the aspects of plant balance, utilisation, and the manufacture of small components, especially for machine tools.

MEASURING METHODS, INSPECTION.

Quality Control, by H. Howell. (*Aircraft Production, February, 1945, Vol. VII, No. 76, 5 pp., 12 figs.*).

Part II. This part continues the analysis of the results obtained from the system described in Part I.

Magnetic Crack Detection, by J. E. D. Bell. (*Aircraft Engineering, February, 1945, Vol. XVII, No. 192, 3 pp., 5 figs.*).

Part I. Principles and operational practice are fully described.

Testing the Thickness of Non-ferrous Castings, by B. M. Thornton. (*Engineering, 2nd February, 1945, Vol. 159, No. 4125, 2 pp., 7 figs.*).

Various electrical systems of measuring wall thickness are outlined; these have certain disadvantages, and the development and operation of a further instrument to suit the particular problems encountered in testing castings are described. The actual use of the instrument is described in detail.

The Sonigage, by Wesley S. Erwin. (*Aircraft Production, February, 1945, Vol. VII, No. 76, 2 pp., 1 fig.*).

With this instrument supersonic vibrations are used to determine the thickness of material. It is only necessary to have contact with one surface of the section being measured. The simplicity of this instrument is due to the fact that it does not measure the time intervals directly, but rather the frequency at which the work is set into resonant vibration in the thickness direction. Since this resonant frequency in plates of a given metal is directly related to the thickness, the measurement of frequency determines the thickness. It can measure in the approximate range 0.020 in. to 0.400 in. with a maximum error of less than 2%.

PHOTOGRAPHY, RADIOGRAPHY.

Inspection by Radiography, by T. W. Fassett. (*Aircraft Production, February, 1945, Vol. VII, No. 76, 6 pp., 21 figs.*).

A technique developed for the examination of Lancaster tubular welded engine mountings is described. A. V. Roe and Co. Ltd. has agreed to accept it as an alternative to the usual procedure of destructive testing.

PLASTICS, POWDER METALLURGY.

Powder Metallurgy, by E. E. Schumacher and A. G. Souden. (*Metals and Alloys, November, 1944, Vol. 20, No. 5, 16 pp.*).

A useful concise summary. History of development; how metal powders are made; processing operations; products and applications; advantages and limitations. 68 references. Appendix (by editors) gives table of types and U.S. manufacturers of powders, processing equipment and parts. This survey is not claimed to be complete. It does not include hot pressing, furnace design and operation, sintering atmospheres, die design and operation, etc.

(*Communicated by the British Non-Ferrous Metals Research Association*).

RESEARCH.

Lathe Cutting Tests on Aluminium and Aluminium Alloys, by E. von. Burg. (*Eng. Digest, December, 1944, Vol. 5, No. 12, 6 pp., Abstract translation from Schweizer Archiv, June, 1944, Vol. 10, No. 6, 17 pp.*).

Author determines the component cutting forces in relation to cutting speeds for six different materials in hard and soft states. Discussion of chip form.

(*Communicated by the British Non-Ferrous Metals Research Association*).

Effect of Coolant Fluid Temperatures on Cutting Tool Efficiency. (*The Machinist, 17th February, 1945, Vol. 88, No. 45, 4 pp., 8 figs.*).

Tests were made on two coolant fluids, which were applied to cutting tools while at constant temperatures ranging between 55°F. and 150°F. in order to study their effect on tool life, cutting speeds, chip formation and other factors. One fluid was a sulphurized mineral oil and the other an emulsion of 1 part soluble oil and 20 parts water. With the straight oil at commercial cutting speeds, lower coolant temperatures down to 70° F. were beneficial. With the emulsion the lower temperatures were also advantageous, except at low cutting speeds when the chilling of the metal appeared to make it more difficult to machine. The emulsion showed a more beneficial effect than oil on tool life when used at the lower cutting fluid temperatures.

Bearing and Tool Damage by Welding or Galling, by E. L. Hemingway. (*Machinery, 15th February, 1945, Vol. 66, No. 1688, 7 pp., 5 figs.*).

The author examines the reasons and theory of galling, and gives pertinent data on how this action can be minimized. Bearing metals, and other important data on bearing performance also are discussed.

SHOP MANAGEMENT.

An Experiment in Management Education, by R. C. Muir. (*Mechanical Engineering, (U.S.A.), January, 1945, Vol. 67, No. 1, 3 pp.*).

A course in better business management for present and potential managers is described. One of the main objects is to give those concerned a general instead of a departmental outlook, and the classes are largely self-instructed.

Recent Developments on Foremanship, by F. J. Burns Morton. (*The Engineer, 9th February, 1945, Vol. CLXXIX, No. 4648, 3 pp.*).

After defining the foremanship problem the author describes the work of the Ministry of Labour, the Cotton Control Board, Supervisors' Discussion Groups, Foremen's Associations and Foremen's Panels. He then discusses the foreman's status, the controversy as to whether or not foremen should become active members of trade unions, and the ever-growing demand for an Institute of Foremen.

The Foreman and Top Management, by John P. Troxell. (*Personnel, (U.S.A.), November, 1944, Vol. 21, No. 3, 6 pp.*).

As "middle management," the supervisory staff should be sufficiently informed on company plans and policies to enable it to perform its managerial

functions effectively. A programme is described through which one company fosters supervisory understanding of policies and procedures and develop essential skills in its foremen.

The Foreman Expresses his Training Needs, by W. B. Dominick and J. E. Crawford. (*Personnel, U.S.A., July, 1944, Vol. 21, No. 1, 12 pp., 6 figs.*).

Only when the foreman's job is dissected and the importance of each component carefully weighed can a proper supervisory training programme be devised. This article describes the findings of a survey through which management was able to determine exactly what the average foreman does, where he needs help, and the type of courses he prefers. While all the data uncovered may not be directly applicable to other plants, this report points the way to a more factual approach to meeting foreman training needs.

Engineering Production Management—Control or Regulation? by P. E. James. (*The Machinist, 20th January, 1945, Vol. 88, No. 41, 2 pp.*).

The author discusses factors that govern the last approach to the establishment of efficient plant production methods.

Machine Scheduling as a Function of Planning, by W. Metcalfe. (*Machinery-Lloyd, 17th February, 1945, Vol. XVII, No. 4, 4 pp., 4 figs.*).

Satisfactory machine scheduling pre-supposes correct plant load evaluation and material control. Assuming these are satisfactory, the writer describes methods of scheduling.

SMALL TOOLS.

Multiple Thread Milling Cutters, by Roger W. Bolz. (*The Machinist, 3rd, 17th, February, 1945, Vol. 88, Nos. 43, 45, 6 pp., 10 figs.*).

Part I. Thread errors can be overcome through slight cutter design changes. Undercutting by a thread mill can be prevented by correcting the tooth form in accordance with calculations, of which examples are given, to learn the amounts and position of error.

Part II. High speeds and few teeth add to cutter life and accuracy. Cutters should be designed so number of teeth permit maximum feed. Abrasive action and heat will be reduced and add to service life of thread mills.

Tooling for High-Speed Machining of Magnesium-Base Die Castings, by C. Adamski and G. A. Fanning. (*Die Casting, October, 1944, Vol. 2, No. 10, 8 pp.*).

Type of tool designed for high speed machining (from 5,500 up to 14,000 surface ft./min.), of thin walled Mg.-alloy die castings. Carbide tipped flycutters (radial rake angle of 30 degrees) are mainly used).

(*Communicated by the British Non-Ferrous Metals Research Association*).

Diamond Tools in Precision Engineering. (*Standards Review, September,* 1944, Vol. 1, pp. 14-15).

General account of the usefulness of diamond tools for fine boring and turning fine finishes down to 2 micro-in.,; measuring surface roughness instead

of visual inspection. Production life of a diamond turning tool : 3,000 components, path traversed over 550 miles. Attention is drawn to war emergency standards B.S. 1120-1943 and B.S. 1148-1943 for diamond tipped boring and turning tools.

(*Communicated by "Industrial Diamond Review"*)

Forme Tools, by G. G. Williams. (*Aircraft Production, February, 1945, Vol. VII, No. 76, 4 pp., 16 figs.*).

Stamping, folding and embossing tools made from steel cutting rules, and known as cutting and creasing formes, have long been used in the printing and allied trades and for the blanking of gaskets and washers from non-metallic sheet. Forme tools have been developed as a cheap, efficient and time-saving alternative to the methods commonly in use in the aircraft industry. They are particularly suitable for cutting plywood, non-metallic and metal sheet into blanks. They are quickly made, cheap to manufacture, produce parts at high speeds, stand up to batch production, can be repaired if necessary at little cost and save machine time and material. Examples are described.

SURFACE, SURFACE TREATMENT.

Electrostatic Spraying and Detearing, by H. Forsberg. (*Sheet Metal Industries, February, 1945, Vol. 21, No. 214, 6 pp., 8 figs.*).

The part to be sprayed with paint is carried on a conveyor through an electrostatic field which is created by vertical electrodes, charged with 100,000 volts of electricity and located within range of a fixed spray gun. Acquiring a charge as they enter this field, the paint particles are instantly attracted to the part to be sprayed, this being earthed through its own conveyor hook. The paint is drawn to all sides of the part simultaneously. Paint is conserved in two ways : (1) practically all the paint sprayed is deposited on the part, and (2) much less paint is required in each action of the spray gun. Electrostatic finishing also results in a great improvement in finishing quality as a thinner, more flexible paint film is applied, and absolute control and uniformity of film thickness are made possible.

Flash Chrome Plating to Size, by C. L. Tanner. (*Mechanical Engineering, U.S.A., November, 1944, Vol. 66, No. 11, 2 pp.*).

Flash chronium plating is a form of hard chrome plating, with deposits of 0.001 or less. Applications to cutting tools are described.

The Pickling of Steels, by Edward W. Mulcahy. (*Sheet Metal Industries, February, 1945, Vol. 21, No. 214, 5 pp., 7 figs.*).

Part IV. This part deals with the bulk storage and metering of acid.

WELDING, JOINTING.

Evolution of Welding in Shipbuilding, by M. N. Maltseff. (*The Welding Journal (U.S.A.), October, 1944*).

The author discusses the evolution of ship construction from the welding viewpoint and refers in detail to the experience gained during the war in carrying out the emergency shipbuilding programme.

(*Communicated by "Welding"*).

The Welding of Non-Ferrous Metals, by E. G. West. (*Sheet Metal Industries, February, 1945, Vol. 21, No. 214, 11 pp., 10 figs.*).

Part I. This part is of a preliminary nature and discusses weldability, the differences between the available fusion and pressure processes, and the physical properties important in welding.

Carbon Arc Welding, by P. L. Pocock. (*Welding, February, 1945, Vol. XIII, No. 1, 6 pp., 7 figs.*).

A general survey of the process, equipment and applications.

Electrodes, by A. J. Holland. (*The Australasian Engineer, 7th October, 1944, Vol. 44, No. 341, 5 pp.*).

Part I. After a brief historical note the author discusses in detail the functions of the flux and the development of various types with particular reference to work done in Australia.

Welding of Boiler Drums and Unfired Pressure Vessels. (*The Commonwealth Engineer, 1st November, 1944, Vol. 32, No. 4, 4 pp., 2 figs.*).

This article outlines the procedure used in welding of boiler drums and other vessels, including the unionmelt process of high amperage single pass welding.

Resistance Welding Machines, by H. O. Willrich. (*Welding, February, 1945, Vol. XIII, No. 1, 5 pp., 2 figs.*).

Their care and maintenance are described. Attention is given to the electric system including the timing circuit, the air and water cooling systems and the maintenance of electrodes and seam welding wheels.

The Spot Welding of 0.0375 in. Aluminised Low-Carbon Steel, by H. W. Brown. (*Welding, J. (J. Amer. Weld. Soc.), September, 1944, Vol. 23, No. 9, 16 pp.*).

An investigation on spot welding of low-C steel clad with Al/8.5Si/0.25Mg alloy. The weldability was found to be similar to ordinary low C steel, except that short welding times should be used to avoid damaging the external cladding and the corrosion resistance.

(*Communicated by the British Non-Ferrous Metals Research Association*).

Hardsurfacing by Welding, by M. Riddihough. (*Machinery Lloyd, 3rd February, 1945, Vol. XVII, No. 3, 3 pp.*).

The ultimate object of applying a hard surface is to enable the component to resist wear which can be divided into abrasion by non-metallic particles and metal wear. There are four groups of rods available for: (1) Less than 20% alloy content. These can be subdivided into machineable and non-machineable alloys. (2) High alloy steels including high speed steel for cutting tools. (3) Non-ferrous alloys. (4) Carbides. The welding and heat treatment techniques are briefly described.

Welding and Brazing of Aluminium. (*Mechanical World, 2nd February, 1945, Vol. 117, No. 3031, 4 pp., 7 figs.*).

Part I. Basic factors in weldability, properties of the alloys, available processes, and the technique of gas welding.

Electronic Controls for Resistance Welding. (*Machinery, 8th February, 1945, Vol. 66, No. 1687, 6 pp., 7 figs.*).

After briefly describing the principles of resistence welding and its control, the author discusses non-synchronous and synchronous timing control, elements of the spot-weld cycle, the classification of timers, the control of voltage variation, electronic control for the storage-type of welder, and electronic controls with special functions.

Riveting of Wrought Aluminium Alloys. (*W.L.A.D.A. Information Bulletin, No. 8, October, 1944, 48 pp., Price 1s., B.N.F., Serial 27,861*).

Selection of rivet alloys; identification; types and manufacture of rivets; design of riveted joints; drilling practice; riveting practice; rivets for special purposes; automatic riveting; inspection and mechanical testing. Appendix on heat-treatment of Al alloy rivets. Bibliography.

(*Communicated by the British Non-Ferrous Metals Research Association*).

WELFARE, ACCIDENTS.

The Effect of Full-pay Sick Leave. (*Personnel, U.S.A., Vol. 21, No. 2, 12 pages, 3 figs.*).

The article is an example of how one company marshalled its arguments against demands for full-pay sick leave. It has been almost universal experience that giving employees full pay results in a sharp increase in the amount of time lost.

Annual Report of the Chief Inspector of Factories. (*Production and Engineering Bulletin, January, 1945, Vol. 4, No. 26, 2 pp.*).

Brief extracts from the report for 1943.

WORKS AND PLANT.

Comfortable Seating. (*Production and Engineering Bulletin, January, 1945, Vol. 4, No. 26, 4 pp., 8 figs.*).

Notes on an important and often neglected subject.